Random Probability Analysis of the $^{48}Ca + ^{249}Cf$ Experiment

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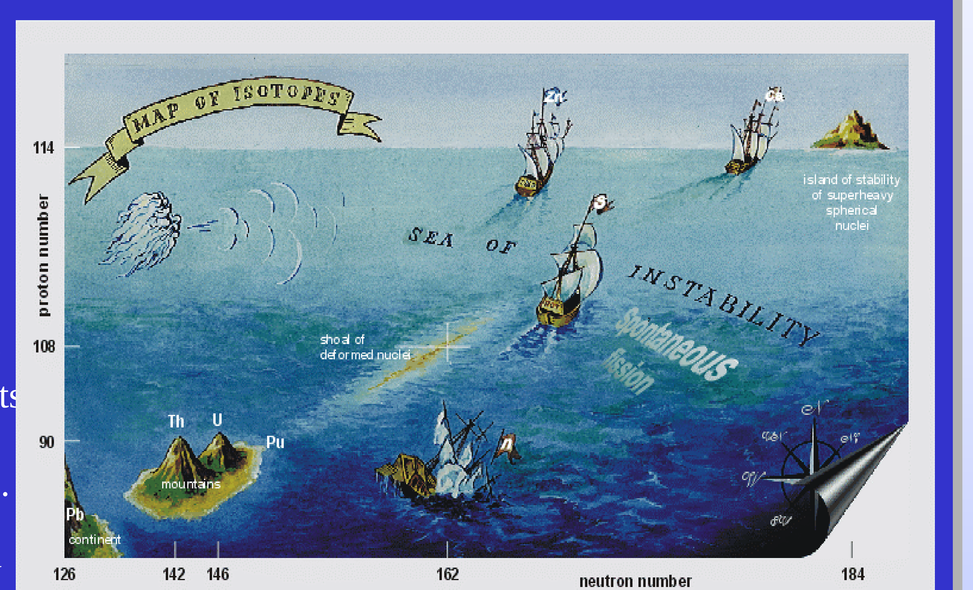
Introduction

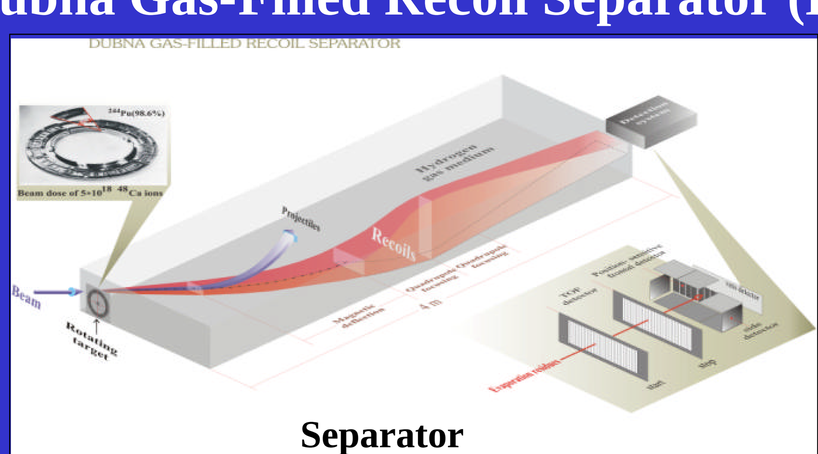


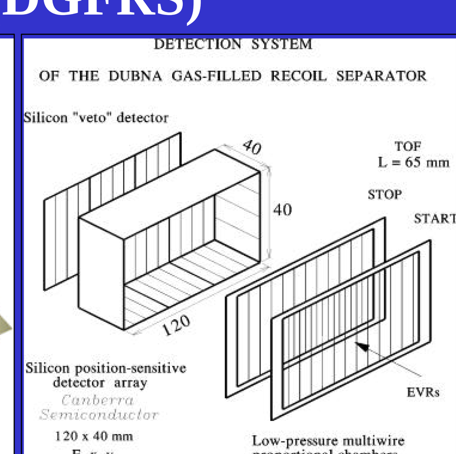
One of the outcomes of nuclear structure theory and the shell model is the possible existence of an "Island of Stability". This Island of Stability resides beyond the heaviest known stable isotopes of lead and bismuth, beyond the long-lived isotopes of uranium and plutonium. The only possible way of observing these superheavy elements is through their production using heavy ion beams and stable/long-lived isotope targets. Various theoretical calculations have been performed over the past 35 years that show the Island of Stability resides somewhere near Element 114, near the predicted closed shells Z = 114 and N = 184. This "Island of Stability" has been reached using ^{48}Ca ion beams and highly enriched plutonium, curium and californium targets.

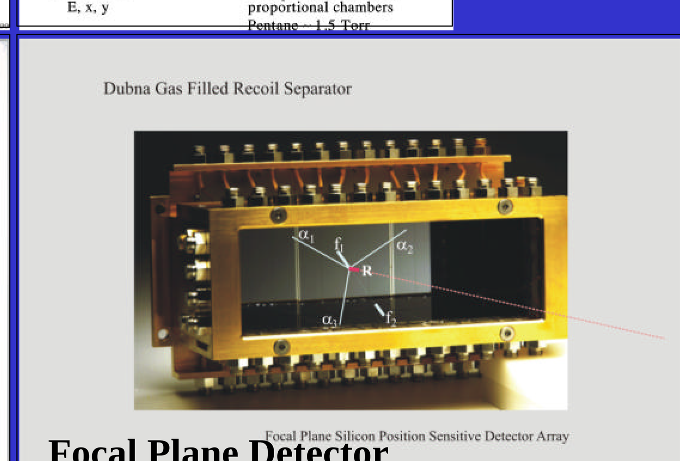
Production/Separation/Detection

Elements 114, 116 and 118 were produced at the U400 Cyclotron at FLNR, JINR, Russia. The U400 accelerates ^{48}Ca ions to energies between 230 and 250 MeV at average intensities of 4×10^{12} particles per second. The accelerated ^{48}Ca beams strike actinide targets with average thicknesses between 230 and 370 μg/cm². Fusion recoils, transfer products, and unscattered beam ions then enter the Dubna Gas-Filled Recoil Separator (DGFRS). DGFRS is filled with hydrogen gas at low pressure, which allows charge exchange collisions between recoiling products and the hydrogen gas. An equilibrium charge state is established for all of the recoiling products. The wanted evaporation residues from the beam-target reaction are then separated from unwanted products using dipole and quadrupole magnets, and focused into the detection apparatus. The detection apparatus consisted of a TOF system followed by an array of 40×40 mm² position sensitive silicon detectors. The detection efficiency for α decays was 87% of 4π. Depending on the reaction, 30-40% of the 114 and 116 reaction products produced at the target make it to the focal plane detector.

Dubna Gas-Filled Recoil Separator (DGFRS)



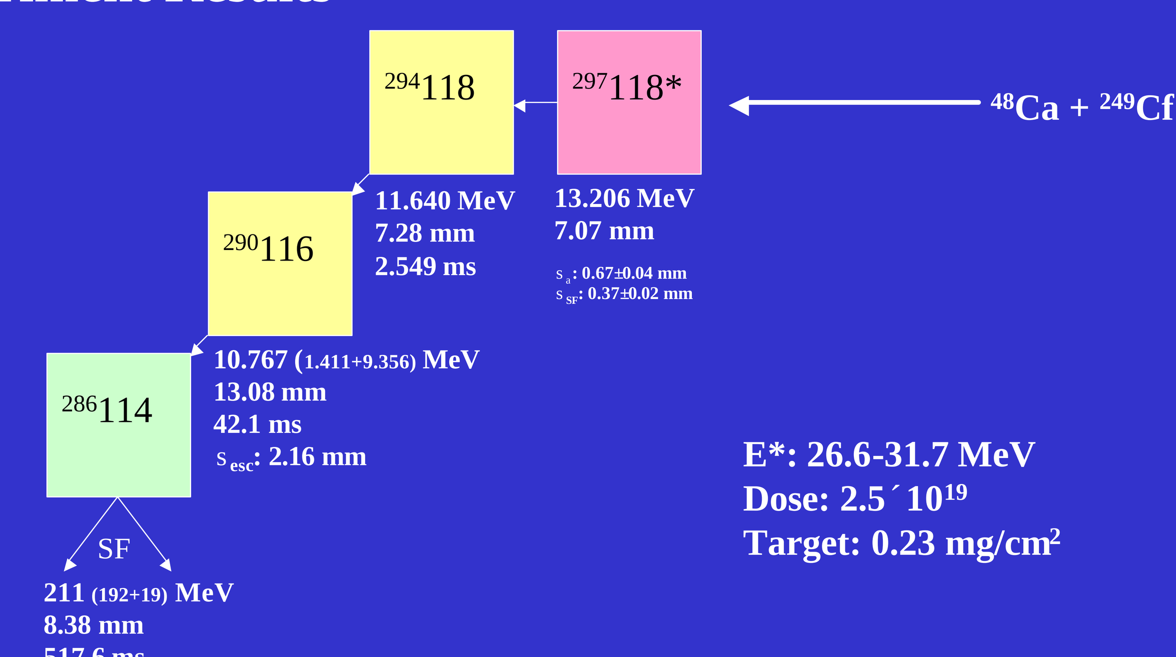




Random Probability Analysis

A long experimental run was performed at the Dubna U400 Cyclotron Facility bombarding ^{249}Cf with ^{48}Ca aimed at producing isotopes of Element 118. The experiment was performed between January 28, 2002 and June 30, 2002. Recent independent data analysis of the information gathered during this experiment was performed at LLNL and is shown below. The two interesting events corresponding to the possible decay of element 118 are shown. The Monte Carlo random probability analysis developed at LLNL* for such heavy element experiments was performed for these data. This method has already been used to analyze the random probability of observing events from the 114 and 116 experiments. *N. J. Stoyer, et al., NIM **A 455**, 433 (2000).

$^{249}Cf+^{48}Ca$ Experiment Results



E*: 26.6-31.7 MeV
Dose: 2.5´10[19]
Target: 0.23 mg/cm²

Monte Carlo Random Probability

Method

1. Create file of random fissions that will be inserted into the original data
2. Sort the fissions so they occur in time order
3. Run analysis code to search for recoil- α, recoil-α-α, recoil-fission, recoil-α-fission, and recoil-α-α-fission correlations with the random fission set
4. Apply any nuclear property systematics to reduce the probability further

Parameters

1. $1\times10^{3-6}$ fissions randomly inserted into the data, random positions, random detector strips
2. Recoil range: 4 MeV < E_{recoil} < 18 MeV
3. α_1 range: 10 MeV < E_α < 12 MeV
4. α_2 range: 9 MeV < E_α < 11 MeV
5. Fission range: 170 MeV < E_{fiss} < 300 MeV
6. Position range: ± 3.5 mm
7. Maximum correlation time: 10 ms, 100 ms, 1000 ms

Results

Random Fissions Inserted	Fissions Observed	Recoil-Fissions	Probability (%)	Recoil-α-Fissions	Probability (%)	Recoil-α-α-Fissions	Probability (%)
990	987	35	3.546	0	0	0	0
10000	9976	320	3.208	0	0	0	0
100000	99753	2780	2.787	0	0	0	0
1000000a	997410	28017	2.809	2	2.005×10^{-4}	0	0
1000000b	997499	27951	2.802	0	0	0	0
1000000c	997424	27908	2.798	0	0	0	0
1000000d	997550	27903	2.797	0	0	0	0
10000000	9972201	278962	2.797	3	3.008×10^{-5}	0	0
14111000	14072800	393876	2.799	5	3.553×10^{-5}	0	0

Conclusions

Based on the early results of the analysis a few conclusions can be drawn:

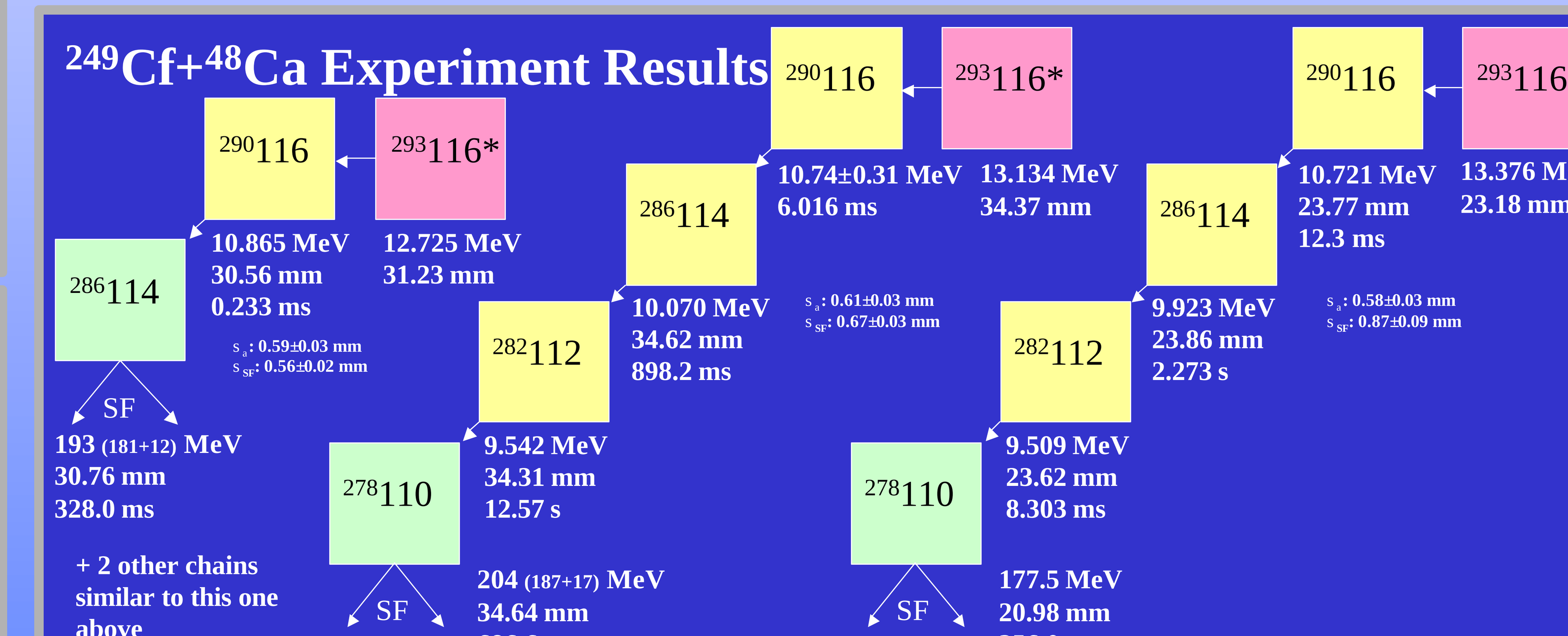
1. It appears that the probability of a random fission correlating to a recoil is around 2.8%.
2. The probability of a random fission correlating to a recoil-α correlation is around 3.5×10^{-5}%.
3. Based on the above probabilities it is assumed that the probability of a recoil-α-α correlation being correlated to a random fission would be less than 7×10^{-6}%.
4. Further work with a larger set of random fissions is needed to calculate the recoil-α-α random fission correlation probability.

Additional Experiments

Based on the successes of the experiments to produce Elements 114, 116, and now possibly 118, an experiment was undertaken to search for the decay daughters of Element 118 in the reaction of ^{48}Ca + ^{245}Cm. Hopefully the decay of the isotopes of Element 116 produced in the experiment would be similar to that observed in the 118 experiment. A random probability analysis is planned for this experiment as well.

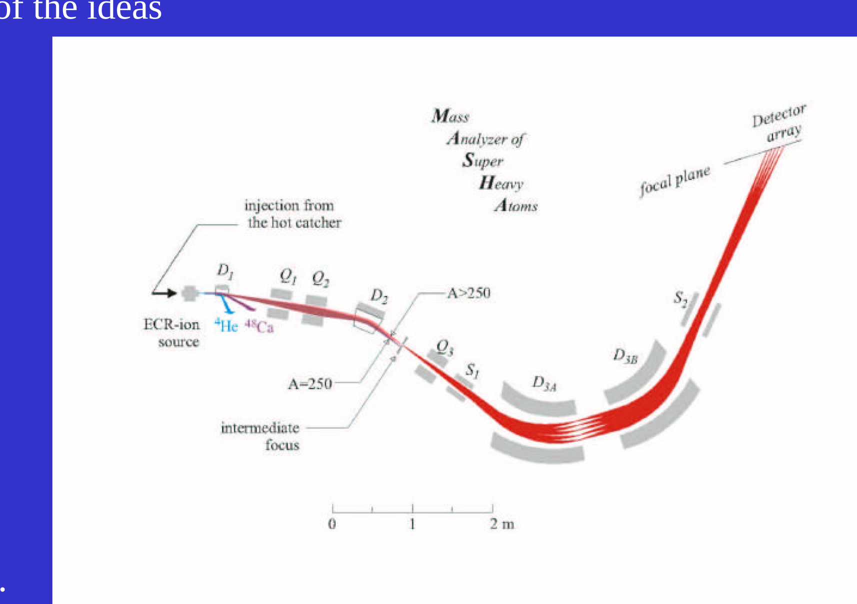
Very Preliminary results are presented below.

$^{249}Cf+^{48}Ca$ Experiment Results



Future Heavy Element Experiments

In the past, new isotopes of heavy elements were discovered through their connection to known isotopes through their decay daughters. To overcome the difficulties inherent in identifying new isotopes of heavy elements when there is no connection to known isotopes, another means is needed to positively identify the Z of these new elements. One of the ideas proposed in our collaboration is the use of a mass analyzer to separate out lower Z atoms to focus only certain Z elements on a focal plane detector. MASHA or Mass Analyzer of Super Heavy Atoms will take recoils from the collision of a ^{48}Ca beam and a ceramic uranium or plutonium target, ionize them and accelerate them through a series of magnets, finally being focused onto a focal plane detector. It is the aim of this apparatus to positively identify new isotopes of the heavy elements through a direct correlation of decay energy and mass.



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